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(54) **A method and apparatus for forming fine particles**

Verfahren und Gerät zur Herstellung von feinen Teilchen

Procédé et appareil pour la fabrication de poudre fine

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(56) References cited:
DE-A- 3 407 608 GB-A- 1 523 637
- Section PQ, Week 8348, 18 January 1984 Derwent Publications Ltd., London, GB; Class P41, AN 83-214864 &SU-A-992 094 (SHLYAPIN V P) 30January 1983

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Description

This invention relates to a method and apparatus for pulverizing ceramic particles or the like to a fine particle composition.

BACKGROUND OF THE INVENTION

Most of ceramics are made of sintered ceramic particles. The Korn grain diameter of the particles influences the physical characteristics of the sintered ceramic material.

For example, the smaller the grain diameter, the higher the sintering activity of the ceramic particles, producing sintered ceramics having high density and superior mechanical characteristics. However, if the grain diameter is too small compared with the size of the sintered ceramics, the particles tend to be filled unevenly; thus, it may lower the density of the sintered ceramics.

As seen in the above, the grain diameter of the ceramic particles is a main factor in determining the characteristics of sintered ceramics. Conventionally, the fine ceramic particles are produced by mechanical crushing methods such as a ball mill or several other types of crushers.

However, the conventional mechanical crushing methods have not been successful at crushing the particles to the desired grain diameter. Moreover, the conventional method disadvantageously takes a long time to form the fine particles.

In the GB 1 523 637 a method and an apparatus for processing material is described. As it can be seen from fig. 6 of the before mentioned document an embodiment, consisting of several working chambers which are arranged one under the other is disclosed and which is enveloped by a continuous solenoidal winding, for activating the magnetic elements, providing inside the working chambers, for crushing the material to be processed. The arrangement of the windings of both sides of the embodiment is fixed and the acceleration of the to be processed material is based on a special power supply to the windings. The disadvantage of this solution is the high energy consumption for the windings.

In difference to the embodiment of the before mentioned British document a metallurgy and construction materials crusher is disclosed in SU 992 094, which employes permanent magnets. The permanent magnets can turn about a vertical axis so that an alternating magnetic field can be produced inbetween the working chambers in which ferro-magnetic balls are provided, interacting with the alternating magnetic field. Due to the rotation motion of the permanent magnets the ferromagnetic balls are accellerated onto circular trajectories.

Finally in the DE 34 07 608, especially a ball mill, is disclosed, which comprise a drum of a ball mill rotating about an axis. This technic is just conventional for minimizing the grain diameter of the to be crushed particles.

All the before mentioned technics disclosed in the cited references needs an ordinary long time to form the fine particles.

Objectives and Summary of the Invention

The objective of the present invention is to provide an apparatus for forming the fine ceramic particles of a desired grain diameter in a short period of time.

The structure of the present invention in order to accomplish the above objective is described in the following.

The apparatus of the present invention for forming fine ceramic particles works as follows coarse particles are placed between a plurality of magnetic crushing media, wherein a plurality of magnetic crushing media are aggregated and diffused repeatedly due to an external moving magnetic field so that the particles can be pulverized thereby.

According to the pulverizing process, when a plurality of magnetic crushing media are aggregated and diffused due to the external magnetic field from the outside, the coarse particles are broken up into tiny particles and pulverized by the magnetic crushing media.

The crushing apparatus of the present invention comprises: a cylindrical case made of non-magnetic material through which the particles to be crushed pass; a plurality of magnetic crushing media provided inside the cylindrical case; a magnetic force generating means provided outside the cylindrical case; a control means of the magnetic force generating means controlling the magnetic force applied to a plurality of magnetic crushing media so that aggregation and diffusion of a plurality of magnetic crushing media are repeated.

In the present invention, a plurality of magnetic crushing media can be aggregated and diffused repeatedly inside the cylindrical case due to the moving magnetic field which is generated by the magnetic force generating means and controlled by the control means. Inventively the control means drives the magnetic force generating means in a way of rotating, stopping and moving upwardly and downwardly, so that a plurality of magnetic crushing media can be aggregated and spread repeatedly. When the particles pass through a plurality of magnetic crushing media, which are repeatedly aggregated and diffused, they are crushed and finally pulverized therein.

Brief Description of the Drawings

Figure 1 is a simplified diagram showing structure of a preferred embodiment of the crushing apparatus of the present invention.

Figure 2 is a cross sectional view of the magnetic crushing media of the crushing apparatus of Figure 1.

Figure 3 is a longitudinal sectional view showing aggregation of the magnetic crushing media.

Figure 4 is a diagram showing a relationship between the grain diameter of the magnetic crushing

media and the degree of the aggregation of the crushing media in the crushing apparatus of Figure 1.

Figure 5 is a diagram showing a relationship between the magnetic force (gauss) and the degree of the aggregation of the crushing media in the crushing apparatus of Figure 1.

Figure 6 is a top view showing the operation of the crushing apparatus of Figure 1.

Figure 7 is a longitudinal sectional view showing the operation of the crushing apparatus of Figure 1.

Figure 8 is a longitudinal sectional view showing the further operation of the crushing apparatus of Figure 1.

Figure 9 is a flow chart showing the operation of the crushing apparatus of Figure 1.

Figure 10 is a diagram showing a relationship between the grain diameter of the crushing media and the grain diameter of the ceramic particles in order to explain the effect of the crushing apparatus of Figure 1.

Figure 11 is a longitudinal sectional view showing an alternative embodiment of the crushing apparatus of Figure 1.

Figure 12 is a diagram showing the operation of the crushing device shown in Figure 11.

Figure 13 is a diagram showing an example of use of the crushing apparatus shown in Figures 1 and 11.

Description of the Preferred Embodiments

Figure 1 is a simplified diagram showing the structure of a preferred embodiment of the crushing apparatus of the present invention. The crushing apparatus 1 comprises: a cylindrical case 3 wherein ceramic particles to be pulverized pass through; crushing devices 4 (4a-4c) which sequentially crush ceramic particles 2 provided in said cylindrical case 3; a pan 5 which receives the pulverized ceramic particles 2' therein.

Said cylindrical case 3 is a non-magnetic member which is made of a material such as aluminum. The cylindrical case 3 is preferably a circular shaped cylinder, but other shaped cases such as a rectangular or other polygon shaped case having openings at its top and bottom are also possible in this invention. In the upper part, the cylindrical case 3 has an opening 3a into which the ceramic particles 2 are fed. At the bottom, the cylindrical case 3 has an exit port 3b through which the pulverized ceramic particles 2' are discharged.

A first crushing device 4a is positioned in the upper part of the case 3, wherein the ceramic particles 2 are roughly pulverized. A second crushing device 4b is positioned in the middle part of the case 3, wherein the ceramic particles 2 are moderately pulverized. A third crushing device 4c is positioned in the lower part of the case 3, wherein the ceramic particles 2 are finely pulverized. Although only 3 stages of the crushing devices 4 are shown, any number of stages of the crushing devices are applicable in the present invention. In general, the more the number of crushing stages, the higher is the efficiency of forming the fine particles. Each of the crushing device 4 (4a-4c) are comprised of: grids 6 (6a-6c) which are provided inside the case 3 so as to lay across the case 3; a plurality of magnetic crushing media 7 (7a-7c) which are placed on said grids 6 (6a-6c); permanent magnets 8 (8a-8c) which are provided outside the case 3 as magnetic force generating means, wherein said permanent magnets 8 are adapted to be rotatable and movable upwardly/downwardly; and driving parts 9 (9a-9c) which rotate and move the permanent magnets 8 (8a-8c) upwardly/downwardly. The permanent magnets 8 (8a-8c) may also be adapted to move diagonally.

The mesh openings in the grids 6 (6a-6c) provided in the crushing devices 4 (4a-4c) diminish as the position of the grid is lower, i.e., the lower the position of the grid is, the smaller the diameter of the mesh becomes. The mesh diameters in the grids 6 (6a-6c) are determined in the range of 30-100 μm and are smaller than the size of the corresponding magnetic crushing media 7 (7a-7c). As shown in Figure 1, the magnetic crushing media 7a-7c can be of different sizes with each other depending on the upper, middle and lower part of the case 3. In such a case, the magnetic media 7 in the upper part of the case 3 are preferably larger in diameter than the ones in the lower stages, which will increase the efficiency for forming the fine particles.

As shown in Figure 2, each of the magnetic crushing media 7 (7a-7b) comprises a globular-shaped magnetic ferrite particle 71. Said ferrite particle 71 is coated with a thin film 72 of zirconium oxide (ZrO_2) or the like, having high mechanical strength, by the sol/gel method. As shown in the diagram of Figure 4, the finest particles can be obtained when the diameter of the ferrite particles 71 is about 110 μm, that is, the aggregation degree of the ferrite particles 71 becomes about 1. Said "aggregation degree" is defined as a relative expression of attractive force between the ferrite particles 71 when the ferrite particles 71 are lined up without gaps by the effect of the permanent magnet 8 as in Figure 3. As shown in Figure 5, the stronger the magnetic force becomes, the more the aggregation degree is increased. The above mentioned optimum diameter of 110 μm for the ferrite particles 71 at the aggregation degree 1 was obtained experimentally rather than analytically.

The driving parts 9 (9a-9c) are adapted to rotate or vertically move the permanent magnets 8 (8a-8c). Since the magnetic crushing media 7 (7a-7c) include the ferrite particles 71 which are magnetic substances, they follow the motion of the permanent magnets 8 (8a-8c) due to the attractive forces therebetween. Namely, when the permanent magnets 8 (8a-8c) are rotated as shown in Figure 6, the magnetic crushing media 7 inside the case 3 also rotate and therefore diffuse. On the contrary, as shown in Figure 7, when the magnets 8 (8a-8c) are moved downwardly below the grids 6 (6a-6c), the magnetic crushing media 7 change to the diffusion state from the aggregation state due to lack of attraction by the magnets 8 (8a-8c). Furthermore, when the permanent magnets 8 are driven in an upward and

downward manner, as shown in Figure 8, the magnetic crushing media 7 diffuse again. Therefore, due to the repetition of aggregation and diffusion, the ceramic particles 2 are gradually crushed into smaller grains.

Next, the operation of the above crushing apparatus is described in the following by referring to the flow chart in Figure 9, as a preferred embodiment of the method of the present invention for forming the fine particles.

First, an appropriate amount of the ceramic particles 2 is supplied through the opening 3a of the cylindrical case 3 (S1). Next, the driving portion 9a of the first crushing device 4a induces the repetitive aggregation and diffusion of the magnetic crushing media 7a, by making the permanent magnet 8a repeat motions of: rotate-stop-move upwardly/downwardly-stop (S2). Thus, the ceramic particles 2 supplied through the opening 3a are roughly crushed therein (S3). The ceramic particles 2 crushed roughly in the first crushing device 4a fall into the next process through the mesh of the grid 6a. In the second crushing device 4b, the repetitive process of the aggregation and diffusion (S2) is applied to the ceramic particles 2 which have been crushed roughly in the first crushing device 4a. The ceramic particles 2 are therein crushed moderately (S3) and fall into the third process. In the third crushing device 4c, the ceramic particles 2 crushed moderately in the second crushing device 4b are crushed finely (S3) by the repetitive process of the aggregation and diffusion (S2). The crushed ceramic particles 2 are then emitted through the exit port 3b of the case 3 onto the pan 5. Hence, the ceramic particles 2' which have been finely pulverized are emitted through the exit port 3b of the case 3 onto the pan 5 (S4).

According to the above-mentioned embodiment, as shown in the test result (Figure 10) of the present invention, the diameter of the pulverized ceramic particles 2' can be controlled merely by controlling the diameter of the magnetic crushing media 7. Therefore, the method and apparatus for forming the fine particles can provide the fine ceramic particles 2' at the desired diameter, preferably larger than 1 μm. In addition, since the crushing apparatus of the present invention includes a plurality of crushing stages or positions having the magnet crushing media 7a-7c, i.e., the upper part, the middle part and the lower part in the case 3, it can produce the fine ceramic particles in a considerably shorter period of time than the conventional crushing method. It is also possible to crush the particles which are suspended in a fluid. Furthermore, the embodiment of Figure 1 of the present invention, wherein the magnetic crushing media 7 is driven by the permanent magnet 8, is suitable to a relatively small plant, since the magnetic force of the permanent magnet is relatively small. In addition, in the embodiment of Figure 1, since the magnetic effect or magnetic force of the permanent magnets 8 is relatively small, and thus the movement of the magnetic crushing media 7 is less vigorous, it will not make a big noise.

Figure 11 is a cross sectional view showing a crushing device 10 which is another example of the crushing device 4 in the crushing apparatus 1 shown in Figure 1. As shown in Figure 11, an electromagnet 18 can be used instead of the permanent magnet 8. As is well known in the art, the electromagnet is formed, for example, of an electric coil and a magnetic core for generating a magnetic field by supplying an electric current to the coil. In this case, as shown in Figure 12, the same effect can be obtained without moving the position of the electromagnet 18, by applying low-frequency current in the range of 0.1-1 Hz.

With the above-mentioned embodiment, as well as the crushing apparatus 1 shown in Figure 1, the grain diameter of the fine ceramic particles 2' can be controlled by controlling the grain diameter of the magnetic crushing media 7. Thus, the method and apparatus for forming the fine particles can provide fine ceramic particles 2' at the desired grain diameter, preferably larger than 1 μm, in a short period of time as described above. In addition, the embodiment of Figure 11, wherein the magnetic crushing media 7 is driven by the electromagnet 18, is suitable to a relatively large plant, since the electromagnet 18 can usually provide a larger magnetic force than the permanent magnet 8 of Figure 1 by supplying a larger driving current to the electric magnet 8.

Figure 13 shows an example of a plant which utilizes the crushing apparatus 1 and 10 shown in Figures 1 and 11, wherein crushing process can be repetitively performed in a closed cycle.

Further, the present invention is not only limited to the above-mentioned embodiments, but can also be utilized in other forms without changing the gist of the present invention. For example, the ceramic particles are used in the description of the present invention as the crushing object; however, regardless to say, other particles can also be crushed.

The present invention has the following effects.

The method for forming the fine particles in the present invention employs the magnetic effect applied from the outside in order to aggregate and diffuse a plurality of magnetic crushing media in a plurality of stages depending on the size of the mesh diameters in the grids. Thus, the method for forming the fine particles can provide the fine particles at the desired grain diameter in a short period of time.

According to the crushing apparatus, a plurality of magnetic crushing media can be aggregated and diffused by a shifting magnetic field which is produced by the magnetic force generating means. Therefore, the crushing apparatus can provide the fine particles at the desired grain diameter in a short period of time.

Claims

1. A crushing apparatus (1) comprising:
   a cylindrical case (3) made of a non-magnetic member, wherein particles (2) to be pulverized pass through said cylindrical case,

a plurality of magnetic crushing media (7a, 7b, 7c) provided inside said cylindrical case (3) and
a magnetic force generating means (8a, 8b, 8c) provided outside said cylindrical case (3),
characterized in,
that a controlling means (9a, 9b, 9c) for driving said magnetic force generating means (8a, 8b, 8c) is provided, for rotating, stopping and moving upwardly/downwardly the magnetic force generating means, so that said plurality of magnetic crushing media (7a, 7b, 7c) can be aggregated and spread repeatedly.

2. A crushing apparatus as defined in claim 1, characterized in that said crushing apparatus further includes a grid (6a, 6b, 6c), said grid having mesh the diameter of which is smaller than said magnetic crushing media (7a, 7b, 7c).

3. A crushing apparatus as defined in claim 1, further characterized in that said cylindrical case (3) includes a plurality of stages in a vertical direction, each of said stages comprising said grid and a plurality of said magnetic crushing media on said grid.

4. A crushing apparatus as defined in claim 1, further characterized in that said magnetic crushing media and said mesh of said grids have different diameters with respect to each said stage.

5. A crushing apparatus as defined in claim 1, characterizing in that said cylindrical cases has openings at the top (3a) and the bottom (3b), said particles (2) to be pulverized are provided at the top opening and the resulting fine particles are output at the bottom opening.

6. A crushing apparatus as defined in claim 1, further characterized in that said cylindrical case has a circular shape.

7. A crushing apparatus as defined in claim 1, further characterized in that said magnetic force generating means is formed by a permanent magnet.

8. A crushing apparatus as defined in claim 1, further characterized in that said magnetic force generating means is formed by an electromagnet having an electric coil.

Patentansprüche

1. Zerkleinerungswerk (1) mit
einem zylinderförmigen Gehäuse (3) als nichtmagnetischem Bauteil, wobei zu pulverisierende Teilchen (2) durch das zylinderförmige Gehäuse geführt werden,
einer Vielzahl magnetischer Zerkleinerungsteile (7a, 7b, 7c) im Inneren des zylinderförmigen Gehäuses (3), und
einer außerhalb des zylinderförmigen Gehäuses (3) vorgesehenen Einrichtung (8a, 8b, 8c) zur Erzeugung einer magnetischen Kraft,
dadurch gekennzeichnet,
daß für den Antrieb der Einrichtung (8a, 8b, 8c) zur Erzeugung einer magnetischen Kraft eine Steuereinrichtung (9a, 9b, 9c) vorgesehen ist, welche diese Einrichtung zur Erzeugung einer magnetischen Kraft dreht, anhält und aufwärts/abwärts bewegt, so daß die Vielzahl magnetischer Zerkleinerungsteile (7a, 7b, 7c) wiederholt angelagert und verteilt werden kann.

2. Zerkleinerungswerk nach Anspruch 1,
dadurch gekennzeichnet, daß das Zerkleinerungswerk außerdem einen Siebboden (6a, 6b, 6c) mit solcher Maschengröße aufweist, daß der Durchmesser der Maschen kleiner ist als der Durchmesser der magnetischen Zerkleinerungsteile (7a, 7b, 7c).

3. Zerkleinerungswerk nach Anspruch 1,
dadurch gekennzeichnet, daß das zylinderförmige Gehäuse (3) eine Vielzahl von Stufen in vertikaler Richtung aufweist, von denen jede den Siebboden und eine Vielzahl der magnetischen Zerkleinerungsteile auf dem Siebboden umfaßt.

4. Zerkleinerungswerk nach Anspruch 1,
dadurch gekennzeichnet, daß die magnetischen Zerkleinerungsteile und die Maschen der Siebböden auf jeder Stufe einen anderen Durchmesser aufweisen.

5. Zerkleinerungswerk nach Anspruch 1,
dadurch gekennzeichnet, daß das zylinderförmige Gehäuse oben (3a) und unten (3b) Öffnungen aufweist, wobei die zu pulverisierenden Teilchen (2) an der oberen Öffnung zugeführt und die hergestellten feinen Teilchen an der unteren Öffnung ausgetragen werden.

6. Zerkleinerungswerk nach Anspruch 1,
dadurch gekennzeichnet, daß das zylinderförmige Gehäuse des weiteren eine kreisrunde Form aufweist.

7. Zerkleinerungswerk nach Anspruch 1,
dadurch gekennzeichnet, daß außerdem die Einrichtung zur Erzeugung einer magnetischen Kraft aus einem Dauermagneten besteht.

8. Zerkleinerungswerk nach Anspruch 1,
dadurch gekennzeichnet, daß des weiteren die Einrichtung zur Erzeugung einer magnetischen Kraft von einem Elektromagneten gebildet ist, der eine Stromspule aufweist.

Revendications

1. Appareil désintégrateur (1) comprenant
un carter cylindrique (3) comme son élément non magnétique, les granules à pulvériser (2) étant passés par ledit carter cylindrique,
une pluralité de pièces désintégratrices magnétiques (7a, 7b, 7c) à l'intérieur dudit carter cylindrique (3), et
un dispositif générateur (8a, 8b, 8c) à engendrer une force magnétique, qui est disposé à l'extérieur dudit carter cylindrique (3),
caractérisé en ce
qu'un moyen de commande (9a, 9b, 9c) est prévu à commander ledit dispositif générateur (8a, 8b, 8c) à engendrer une force magnétique, qui tourne, arrête et déplace en haut/en bas ce dispositif générateur à engendrer une force magnétique, de façon qu'on puisse induire l'agrégation et dispersion, à plusieurs reprises, de ladite pluralité de pièces désintégratrices (7a, 7b, 7c).

2. Appareil désintégrateur selon la revendication 1, **caractérisé en ce** que l'appareil désintégrateur comprend de plus un fond de tamisage (6a, 6b, 6c) à une telle grandeur de mailles que le diamètre des mailles soit plus petit que le diamètre desdites pièces désintégratrices magnétiques (7a, 7b, 7c).

3. Appareil désintégrateur selon la revendication 1, **caractérisé en ce** que ledit carter cylindrique (3) renferme une pluralité des étages, en sens vertical, dont chacun comprend ledit fond de tamisage et une pluralités des pièces désintégratrices magnétiques sur le fond de tamisage.

4. Appareil désintégrateur selon la revendication 1, **caractérisé en ce** que lesdites pièces désintégratrices magnétiques et les mailles desdits fonds de tamisage à chaque étage présentent des diamètres différents.

5. Appareil désintégrateur selon la revendication 1, **caractérisé en ce** que ledit carter cylindrique est prévu des ouvertures supérieures (3a) et inférieures (3b), les granules à pulvériser (2) étant alimentés par l'ouverture supérieure et les particules fines produites étant déchargées par l'ouverture inférieure.

6. Appareil désintégrateur selon la revendication 1, **caractérisé en ce** que ledit carter cylindrique présente, de plus, une forme circulaire.

7. Appareil désintégrateur selon la revendication 1, **caractérisé en ce** que de plus ledit dispositif générateur à engendrer une force magnétique est formé par un aimant permanent.

8. Appareil désintégrateur selon la revendication 1, **caractérisé en ce** que de plus ledit dispositif générateur à engendrer une force magnétique est formé par un électro-aimant comprenant un self.

FIG. 1

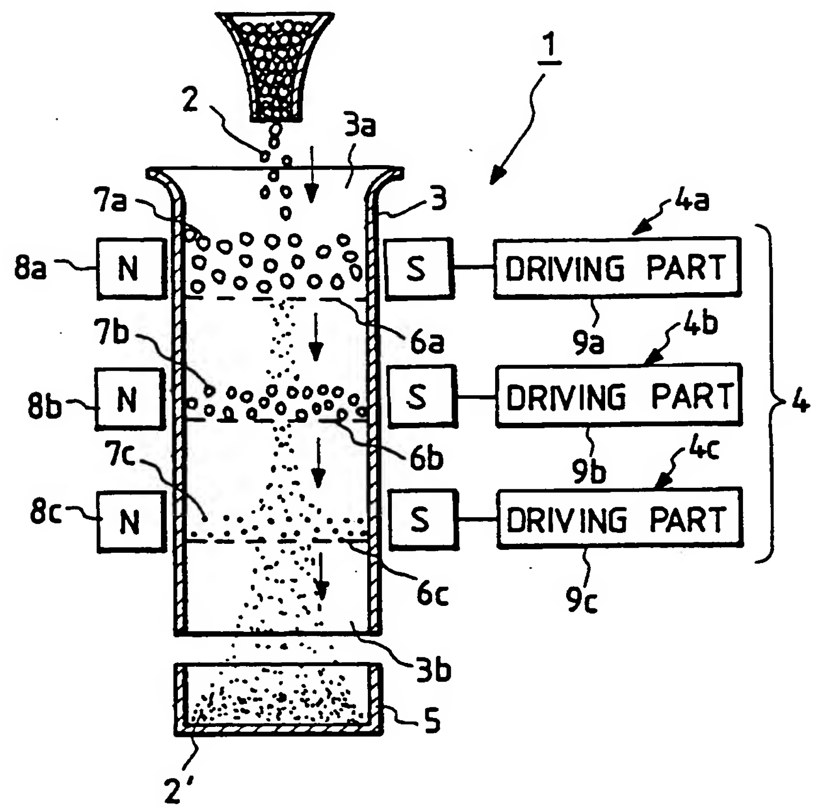
1
2
3a
3
7a
4a
8a
N
S
DRIVING PART
9a
7b
6a
4b
8b
N
S
DRIVING PART
4
7c
6b
9b
4c
8c
N
S
DRIVING PART
6c
9c
3b
5
2'

FIG. 2

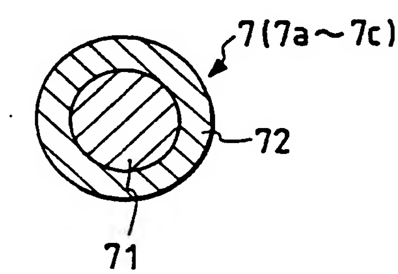
7(7a~7c)
72
71

FIG. 3

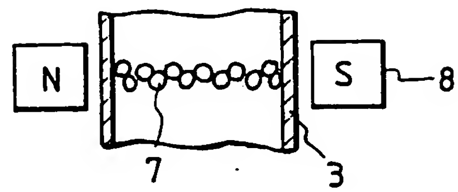

FIG. 4

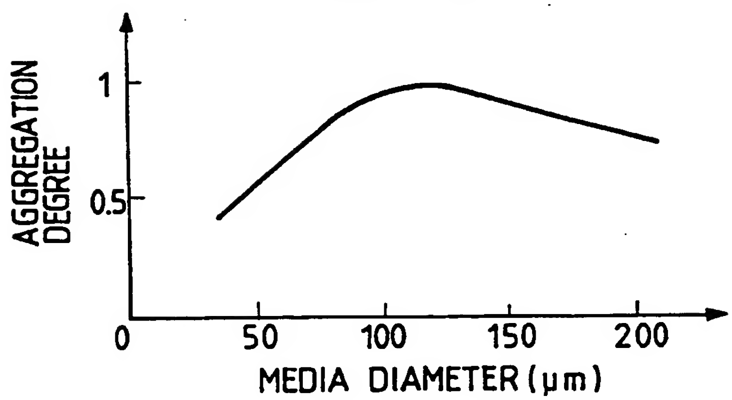

FIG. 5

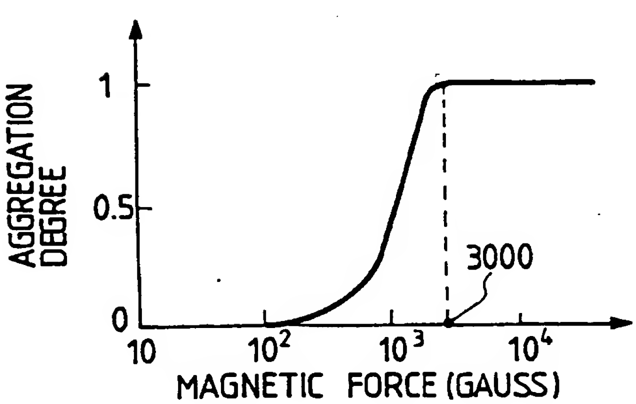

FIG. 6

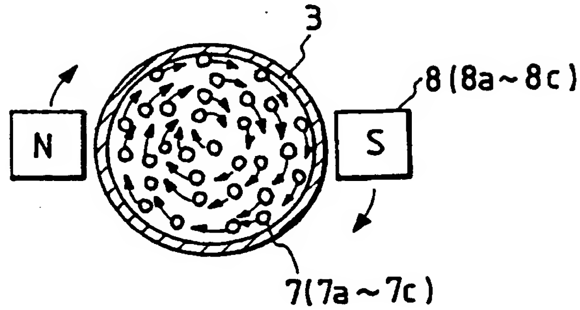

FIG. 7

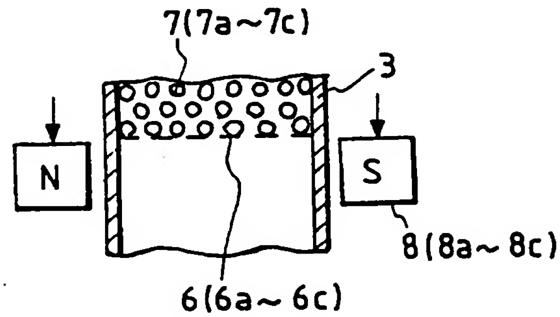

FIG. 8

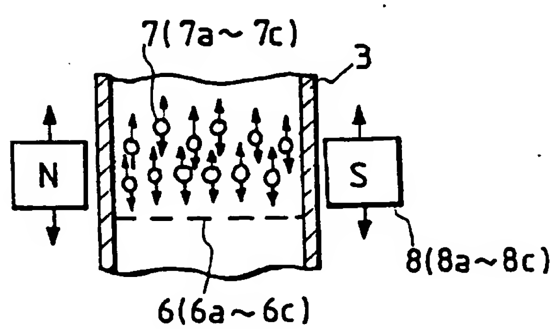

FIG. 9

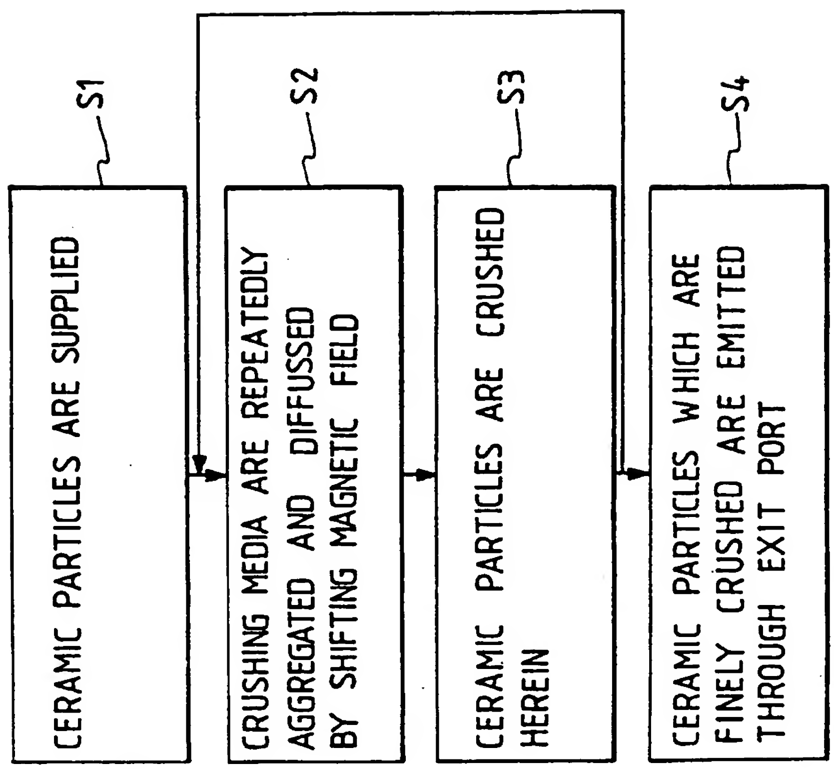
S1
CERAMIC PARTICLES ARE SUPPLIED
S2
CRUSHING MEDIA ARE REPEATEDLY AGGREGATED AND DIFFUSSED BY SHIFTING MAGNETIC FIELD
S3
CERAMIC PARTICLES ARE CRUSHED HEREIN
S4
CERAMIC PARTICLES WHICH ARE FINELY CRUSHED ARE EMITTED THROUGH EXIT PORT

FIG. 10

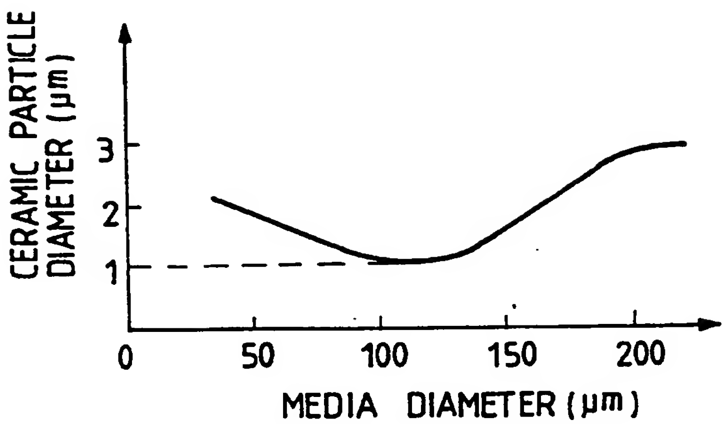
CERAMIC PARTICLE DIAMETER (μm)
3
2
1
0
50
100
150
200
MEDIA DIAMETER (μm)

FIG. 11

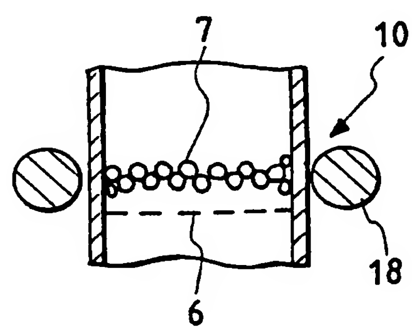
7
10
18
6

FIG. 12

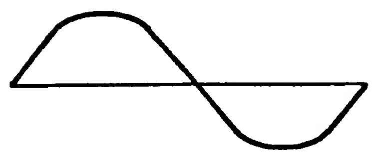

FIG. 13